Novel proposal for V2X systems and WBAN cooperation to improve road safety

Małgorzata Gajewska
Faculty of Electronics Telecommunications and Informatics
Department of Radio Communication Systems and Networks
Gdansk University of Technology
Gdansk, Poland
m.gajewska@eti.pg.gda.pl

***Abstract*— In this paper, a novel proposal of the automotive Vehicle-to-Everything system solution is presented. In this proposal, there are included the Machine to Machine type communication system and the sensor system based on a short-range the Wireless Body Area Network communication. The aim of this paper is the analysis of the model for communication, especially its architecture and signals structure for the proposed solution. The use of cooperation these two systems is a chance to significant improving a road safety.**

Keywords—WBAN, V2X, road safety, 5G, transport

I. Introduction

Nowadays, we observe that the development of various radio communication systems all over the world is very rapid. We know a many various concepts of these systems. For example, on a few years ago the 4th generation LTE system was implemented. After three years operators gave us services of data transmission of the LTE-Advanced system. But now, we have intensive work on the 5th generation system.

In the meantime, the elements of infrastructure of the modern methods of wireless M2M communication (Machine-to-Machine) are described in literature [1, 2]. In general, the M2M communication is the wireless technology of data transmission from a machine (e. g. a car) to a machine (e. g. a train) or from a sensor to a sensor, a mobile to a machine or between terminals. It can be also the transmission of information between a man (e. g. pedestrian) and a machine (e. g. a car). In general, there are different systems that use the M2M communication, e.g. the V2X (Vehicle to Everything) [1, 2].

On the other hand, medical companies invest a lot of money for the development of different propositions of the M2M communication, as a name the Wireless Body Area Network – WBAN. These WBAN networks enable the implementation of signals transmission using special sensors. These sensors may be on-body sensors which are surface-mounted on the body in a fixed position or in-body sensors which can be implanted subcutaneously inside the body, or off-body sensors which are mounted outside the body.

We can list many such examples of WBAN applications. But we don't have many publications on the topics of consolidating these different solutions for the same purpose – increase the safety of people. We need such technical solutions which give us ability to reduce the number of threats.

In this paper, a novel proposal of the V2X automotive system cooperation with a short-range Wireless WBAN type network is studied, as a structural part of this V2X system [3, 4, 5, 6].

II. Characteristics of WBAN with M2M Communications

A. Wireless Body Area Network with the M2M Communication

Typical WBAN network with the M2M communication is shown in Fig.1. The basic elements of the M2M are presented in the red block and the WBAN in the yellow block.

In general, the M2M communication is based on the transmission of data collected from various information sources, e.g. sensors, via the M2M gateway and some data transmission systems to the M2M Application Platform. In the M2M Platform some algorithms for data analysis are implemented[1, 2].

If we consider the WBAN with M2M communication, the role of information sources is to be the on-body sensors, in-body sensors or off-body sensors which are designed to monitor the current state of a person health [5]. As we can see in Fig 1, the sensors can be as follows:

- Sensor for monitoring the brain waves.
- Sensor for measuring the patient's breath.
- Sensor for measuring the level of glucose.
- Sensor for blood pressure monitoring.
- Sensor for read pulse.
- Sensor for ECG.

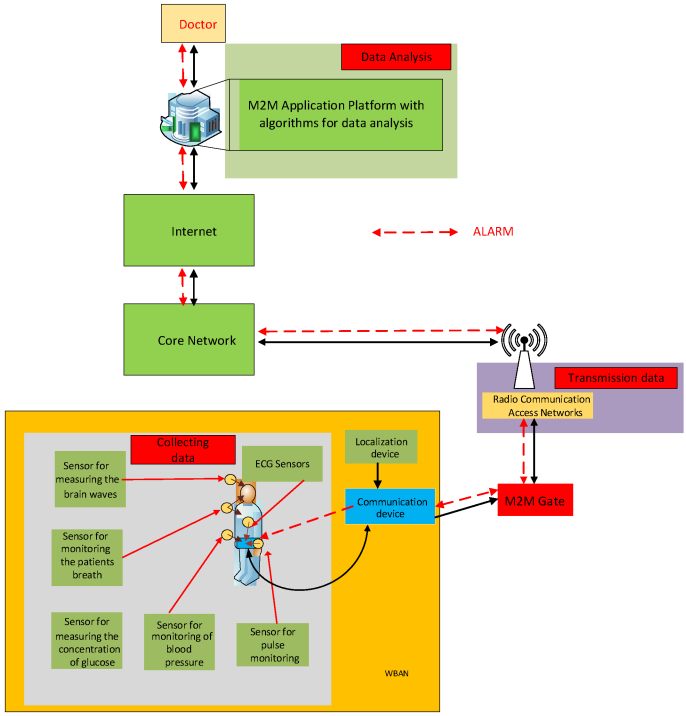

Fig 1. The WBAN with Machine to Machine Communication Systems.

These sensors send signals, in continuous real-time, quasi-real-time or discrete time, with required quality of service (for real time transmission data). These signals are sent to the communication device which is located on man clothes or outside a body. In the next step, this device sends signals, through the M2M gate implemented for communication to a mobile network (e.g. a cellular mobile system, satellite systems or other type systems). Next, this signal is transmitted through the Core Network and Internet and it will be send to the M2M Application Platform.

The Application Platform usually can be located at a server which is typically equipped with specialized software to make some analysis. In the near future, new algorithms and specialized databases will be available for this type of analysis. It is also very likely that elements of cognitive radio can be used for its implementation.

Most often, some artificial intelligence algorithms can be used for data analysis which can take decisions of sending an emergency information to a medical center (a doctor) and/or to a monitored man. Of course, the using artificial intelligence is not included in all applications of WBAN-based medical networks. Whole information can be sent individually or for specified groups, including other network users, in order to use them for different purposes.

If data analysis procedures on the Application Platform detect some problems when the health or life of monitored person is in a danger then the platform sends a feedback information to this person and, additionally, to a doctor. In Fig. 1, this feedback information is noted as the 'alarm' signal and it was drawn by the red dashes line. Then, the monitored person or the doctor can respond appropriately, in extreme cases, saving her life. Moreover, it can contribute indirectly to saving lives of other people because e.g. a car accident can be avoided. But for this reason, a cooperation between WBAN and various types of M2M communication systems is necessary, and it is discussed below in this paper.

B. Example of Wireless Body Area Networks Applications

After analyzing the data in bibliography [6], it can be stated that the WBAN can play a very important role in intelligent transportation systems. These networks may prevent many accidents, which can be the result of sudden health deterioration. This applies to pedestrians, drivers, cyclists, motorists and all other road users.

We have many propositions of the use of WBAN in M2M networks for help the people health but in transport systems, for example [6, 7], it will be necessary for:

- Monitoring people with a heart disease and/or hypertension on a continuous time what can prevent undue and indiscriminate behavior of pedestrians and drivers. Additionally, it can be very important for a driver with congenital central hypoventilation or the so-called Ondine's Curse.
- Remote transmission of results e.g. EEG (Electroencephalography) signals while driving, to e.g. instruct the driver about an impending epileptic attack.
- Automatic monitoring of glucose levels for people with diabetes and remote applying the insulin in appropriate doses and, at the same time, begin the alarm in critical situations.

The second group of WBAN users is very important for transport systems because it allows to provide help for physically or mentally disabled traffic participants. We can mention here:

- Supporting the movement and operation of blind or partially sighted people.
- Automatic communication with disabled persons, for example, in railway stations, to get them necessary help.
- Support to hearing impaired persons and deaf people.

However, the major WBAN application for transport results from the possibility of equipping professional drivers with sensors which can support monitoring their vital functions in order to minimize the risk of an accident. For instance, critical health problems increasing the risk of accident can result from:

- Falling asleep of a driver because we have remote heart and breath monitoring and measuring of brain waves monitoring. Thus, it can be sent by wireless network

automatic startup alarms to a driver in an emergency situation.

- Heart attacks monitoring.
- Test whether the driver is not under the influence of alcohol.
- Stroke.

At this moment, the list of possible applications of the WBAN network with M2M communication is not closed. After the implementation of 5G radio communication networks the rapid development of WBAN systems in transport applications [12] is anticipated. It's obvious that the WBAN can improve safety of all people, increase a passenger comfort and efficiency of health problems detection as well as improve our security. Probably soon, all elements of transport systems will be equipped with WBAN sensors but if we want to prevent road accidents and road traffic violations we must consolidate this WBAN with e.g. M2M communication at V2X systems [6, 7].

III. Novel Proposal for V2X Systems and WBAN Cooperation to Improve Road Safety

A. *V2X Systems as a type of the M2M Communication*

Transport systems also implement various types of M2M radio communications, known as the V2X communication. In the V2X, the communication can be made between vehicles and other vehicles, pedestrians or some elements (sensors) of a road or the cellular systems infrastructure. We can distinguish some subtypes of the V2X communication as following:

- Vehicle-to-Vehicle (V2V) when devices transfer the information directly between vehicles.
- Vehicle-to-Infrastructure (V2I) when devices transmit the information between moving vehicles and the surrounding infrastructure.
- Vehicle-to-Pedestrian (V2P) when the communication is established between cars and pedestrians.
- Vehicle to Home (V2H) when data transmission is made between vehicles and e. g. buildings.
- In Vehicle Communications (In-V) when data are transmitted between different M2M sensors and control devices mounted on vehicles, what allows performing some maneuvers without human intervention.

The rapid development of V2X communications, especially the V2V, is an opportunity to significantly improve our security by developing communications standards that enable reliable, continuous low-level error signals from various sources, and then analyze them in a real time [10, 11].

In December 2015, the 3GPP organization published technical report TR 25.885 (Release 14) [9] for the use of LTE-V for the implementation of V2X communication services, namely to improve communication between vehicles, vehicles and parts of a road infrastructure as well as between vehicles and terminals carried by a pedestrian or a cyclist. It's well known that in this system we have a problem with inter-cell interferences which decrease transmission performance at a cell edge. The algorithm for reducing the interference due to intelligent frequency reuse in LTE-V will be the same as in LTE-Advanced. Some interesting approach of frequency reuse we can find in [8].

B. *Novel Proposal for V2X Systems and WBAN Cooperation*

The proposed solution for cooperation of WBANs and V2X systems can play a great role in the development of transport systems for cars and other vehicles, e.g. trains. It's well known that until 2024, there will be implemented many practical solutions of V2X wireless communication systems [3, 11]. Thus, it is possible the practical implementation of some solutions based on sensor WBANs for improving a road traffic safety.

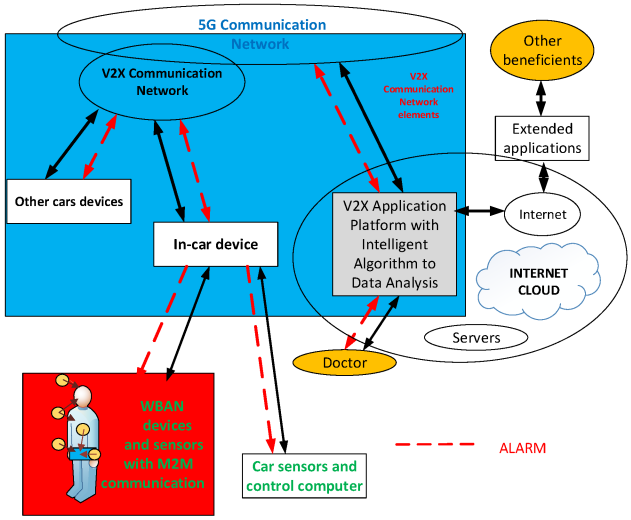

Fig 2. Proposal of Wireless Body Area Networks implementation in transport systems based on V2X.

In Fig. 2, the proposed architecture of WBAN implementation in V2X-based transport systems is presented. This concept is based on the integration of WBAN functionality with V2X communication. In presented system architecture, the red block marks WBAN devices and sensors related to a person, especially, a car driver. Next, we have the 'In-car' device which receives and sends the information from/to the V2V Communication Network and/or the 5G radio communication network as well as, on the other hand, from/to the BAN network. In Fig. 2, we can see the V2X Application Platform with 'Intelligent Algorithms of Data Analysis' for global analysis of data from different 'In-car' devices which are connected with:

- The car control computer.
- Servers for data analysis in a network cloud.
- The medical center and e.g. fire brigades, police etc.

The key is, however, that we have bidirectional data transfer between the WBAN and the V2X. One can see, the V2V communication network is used to transmission of information between vehicles and some elements of a road infrastructure.

The 'In-car' device collects, combines, transmits and receives data from different sources: the V2V network, the local BAN network, the Application Platform, the doctor and others, as well as transmits information to a car computer, if necessary.

The V2X Application Platform probably will be typically located in an Internet cloud. At this platform, we can use 'Intelligent Algorithms of Data Analysis' which enables global analysis of data. These data will send to this platform from different 'In-car' devices and other sources, having effect on the V2X network.

Using an intelligent algorithm for global data analysis enables taking decisions which have effect on work of the whole V2X network. If after intelligent analysis, a problem will be detected at the V2X Application Platform then the alarm signal (see the red, dashes line in Fig. 2) will be sent to both the V2V network and the BAN.

Practical research and analysis provided by the National Highway Traffic Safety Administration (NHTSA) and the ITS JPO (Intelligent Transportation Systems Joint Program Office) show that the use of the V2X system can avoid about 80% of collisions involving two or more vehicles [3]. Thus, if we combine V2X systems with the WBAN we can further improve road safety. Because the WBAN will give us a warning signal about the danger of a driver and/or a passenger.

IV. Proposal of Transmitted Signals Structure in Combined WBAN/V2X Networks

V2X Application Platform data are collected from various sensors. If we consider the V2X system with the WBAN, data will be sent from 'In-car' devices which combine the WBAN and V2X signals, and from other devices which only send e.g. WBAN signals (maybe e.g. drivers) or V2X signals (cars without WBANs). Thus, we have a number of information signals from many sensors. Keep in mind that the number of these individual units involved in a communication network will be very large. Therefore, it is necessary to elaborate analysis of data collected and combined from different devices in whole the V2X network.

The problem is that the V2X Application Platform using artificial intelligence algorithms must take decisions about a single unit (e.g. a driver or a pedestrian) but, also, many components of V2X systems with the WBAN need to be analyzed at the same time. Because it must be done in a real time, it is not physically possible to analyze all the data at all the time. Thus, we need the algorithm which make some groups of devices placed in some list which is continuously actualized. Therefore there is a need to create some rules for dynamic creation of the list of devices, and it can be related to the rules of the V2X network functioning.

In Fig. 3, the proposed structure of signals transmitted between the M2M Communication network, V2X Systems, the WBAN, and the V2X Application Platform is presented. Already at first glance, it can be seen that the problem is complex and requires elaboration of complex algorithms [11].

As one can see, at the first step, sensors of local WBAN placed e.g. in-body of a bus driver send an information to 'In-car' device and next, to V2E communication systems. Then, this information is received by the V2X Application Platform. Based on this information, the platform makes decisions and sends them forward. The efficiency of decision-making and their validity depend on the used artificial intelligence algorithms but also on the technical capabilities of the devices which we have at our disposal. The more innovative the solution will be, after appropriate approvals in the vehicles. Then, the range of possible solutions will be much greater.

As we can see, all over the time the V2X Application Platform sends and receives signals from the V2X Communication Network and the WBAN. Only the full compatibility of these systems guarantees making effective decisions and it will be possible to protect the health, life and property of all users of transport systems.

These decisions, e.g. can be as follows:

- Emergency information which will be sent to selected road infrastructure elements connected to the V2X network. For instance, using this information we can change intelligent signs information, change the lights on a crossroad or drivers will take information than others cars stopped for some parts of a road etc.
- Safety stopping a car when information is sent to expected 'In-car' device, and next, to the control computer of the car. It may happen if the Application Platform has information from WBAN sensors that a driver will probably has got an epileptic attack.
- Alarm information which is transmitted to local in-car WBAN networks.
- Emergency information which is sent to other cars connected to the V2X network, placed at the active list of devices. It can be very useful e.g. for bad weather conditions with high fog.
- Sending information to some pedestrians.
- Speed limitation commands important e.g. when there is a collision on a highway.

This is very important solution because in an emergency, the V2X Application Platform takes this information and activate set of actions in order to prevent a danger. Drivers and pedestrians life is also protected because the car has information from the

V2X and thus, when crossing into the intersection, it can avoid a collision. On the other hand, if the V2P system gets information from the WBAN than a partially sighted people approaching the pedestrian crossing, the system may force response in vehicles, limit the speed, launch beeps or light at the crossing.

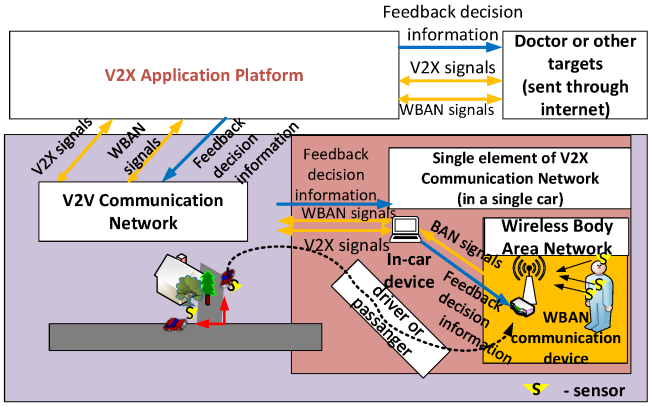

Fig. 3 Structure of signals transmission between the M2M Communication Network, V2X Systems and the WBAN.

Thus, the concept of cooperation both the WBAN and V2X systems this is a real challenge for increasing of a road safety. As we know, such cooperation will also reduce the number of accidents involving people with disabilities. But we need innovative solutions, new artificial intelligence algorithms, and extensive databases to make it work.

V. CONCLUSION

In the paper, a novel concept of the M2M communication system, with cooperation of Wireless Body Area Networks as a structural part of the V2X system, for transport systems telematics, is presented.

As shown, proposed solution can significantly increase safety of all road traffic users (drivers, passengers and pedestrians). This cooperation significantly enhances the functionality and scope of these systems.

From the point of view of transport systems, this is a large step to protect live and health of users of a road and a rail but, additionally, users of maritime and air traffic.

Elements of these systems are already being implemented but to build the full infrastructure still takes some time and financial investment. The proposed solutions will be more advanced after global implementation of 5G systems what gives very good perspective for intelligent transportation systems development.

REFERENCES

[1] M. Gajewska. (2016) "Design of M2M Communications Interfaces in Transport Systems". In: J. Mikulski (ed.) Challenge of Transport Telematics. TST 2016. Communications in Computer and Information Science, vol. 640. Springer, Cham, Switzerland, pp. 149-162. DOI: 10.1007/978-3-319-49646-7_13.

[2] L. Liu, M. Gaedke, A. Koeppel (2005) "M2M Interface: a Web Services – based Framework for Federated Enterprise Management", Proc. of the IEEE ICWS, 2005 DOI: 10.1109/ICWS.2005.72.

[3] Statement of Nathaniel Beuse, (2015) "Associate Administrator for Vehicle Safety Research, National Highway Traffic Safety Administration, Before the House Committee on Oversight and Government Reform Hearing on "The Internet of Cars".

[4] IEEE Standard for Information Technology – Telecommunications and Information exchange between systems – Local and metropolitan area networks – Specific requirements, (2010) Part 11 Wireles LAN Medium Access Control (MAC) and Physical Layer (PHY), Specification "Amendment 6:Wireless Access in Vehicular Enviroments".

[5] E. Jovanow, A. Milenkovic, C. Otto, P. C de Groen (2005) "A wireless body area network of intelligent motion sensors for computer assisted physical rehabilitation", Journal of NeuroEngineering and Rehabilitation. DOI: 10.1186/1743-0003-2-6.

[6] B. Antonescu, S. Basagni. (2013), "Wireless Body Area Networks: Challenges, Trends and Emerging Technologies". In proc. of 8th International Conference on Body Area Networks – BodyNets '13. Boston, Massachusetts, pp. 1-7.DOI: 10.4108/icst.bodynets.2013.253722.

[7] R. J. Kennelly, R. M. Gardner (1997) "Perspectives on development of IEEE 1073: The Medical Information Bus (MIB) Standard", International Journal of Clinical Monitoring and Computing. Netherlands: Kluwer.

[8] S. Gajewski, "Soft-Partial Frequency Reuse for LTE-A," Radioengineering, vol. 26, no. 1, pp. 359-368, April 2017.

[9] 3GPP TR 22.885 v 14.0 (2015) "Study on LTE support for Vehicle to Everything (V2X) services".

[10] S. Gajewski, M. Gajewska, M. Sokol (2011) "Architecture and Basic Assumptions of RSMAD". In: Mikulski J. (ed.) Modern Transport Telematics. TST 2011. Communications in Computer and Information Science, vol. 239. Springer, Berlin, Heidelberg, 2011. DOI: 10.1007/978-3-642-24660-9_23.

[11] J. Harding, G. Powell, R. Yoon, J. Fikentscher, C. Doyle, D. Sade, M. Lukuc, J. Simons, J. Wang (2014) "Vehicle-to-Vehicle Communications, Readiness of V2V Technology for Application". DOT HS 812 014, NHTSA.

[12] P.S. Pandian, K. Mohanavelu, K. P. Safeere, T.M. Kotresh, D.T. Shakunthala, P. Gopal, V. C. Padaki (2008) "Smart vest: Wearable multi-parameter remote physiologital monitoring system", Medical Engineering&Phics, no. 30 DOI: 10.1016/j.medengphy.2007.05.014